Dynamic articulatory control during fricative production: Implications for perception

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Speech production involves a complex interplay between producing maximally recognizable forms and expending minimal articulatory effort. Talkers are sensitive to the listening environment, and they shift their productions to account for potential perceptual difficulties. For example, when producing words from dense phonological neighborhoods, talkers expand the F1xF2 vowel space, thereby differentiating produced words (Munson & Solomon, 2004). Such effects have been taken as evidence of H&H theory (Lindblom, 1990), which posits that talkers aim to find a balance between hypospeech and hyperspeech, although they may also derive from lower-level processes like competition or articulatory planning (Beckman, Helgason, McMurray & Ringen, 2011; McMurray & Trimble, in press).

Prior studies have investigated classes of sounds that have clear, dominant acoustic cues, such as vowels. However, many speech segments lack such straightforward cue mappings. For example, there are at least 24 cues that aid fricative identification (McMurray & Jongman, 2011; Jongman, Wayland & Wong, 2000). When gauging the requisite degree of precision in a production, talkers may choose to emphasize all these cues, or may instead focus on a subset while reducing others; however such analyses are difficult because of the sheer number of cues involved and the lack of tools for grouping them.

This work investigates talkers’ use of cues both within the frication and in the following vocalic portion (vocoid) of CV syllables using a new computational technique for examining the efficacy of collections of phonetic cues. Our goal was to measure how different cues interact in fricative production. We analyzed a corpus of 20 talkers producing each of the eight fricatives of English in CV syllables with six different vowels. Each talker produced three repetitions of each CV, yielding 2880 fricative exemplars. Each of these tokens was measured along 24 acoustic dimensions, including a range of cues within the frication and within the vocoid.

A simple classification model was trained to categorize these fricatives by linearly weighting and combining them and using these as the basis of a logistic regression. These linear weights then give a measure of the strength of each cue, and can combine multiple cues to ask overall how informative they are for fricative identification. We found a tradeoff between cues in the frication and cues in the vocoid (Fig. 1); in general, when cues were weak within the frication portion, cues in the vocoid were stronger. Conversely, when weak vocoid cues were observed, frication cues were stronger. However, talkers rarely produced tokens with strong vocoids and strong fricatives, and even more rarely produced tokens with weak vocoids and weak fricatives.

Examination of individual talkers showed that all showed a negative correlation between the strength of fricatives and strength of vowels (Fig. 2), signifying this tradeoff. However, some speakers showed a stronger relationship than others; we investigated how listeners perceived speech from a subset of these talkers, to determine whether this tradeoff between cues is related to recognition of the tokens. The results from these analyses indicate that articulatory adjustments by talkers are not simply at a coarse grain, but can vary across different cues and talkers. When a fricative is reduced, the vocoid is enhanced to compensate. This pattern appears to vary between talkers, and even across different contexts within a single talker, suggesting dynamic control of articulatory processes. It also has implications for theories of speech perception in that there appear to be many ways to produce a fricative, and listeners may need to be flexible in dealing with multiple cues.
References


*Figure 1: Scatterplot of all exemplars measuring vocoid strength as a function of frication strength.*

*Figure 2: Individual data from four sample participants, measuring vocoid strength as a function of frication strength.*